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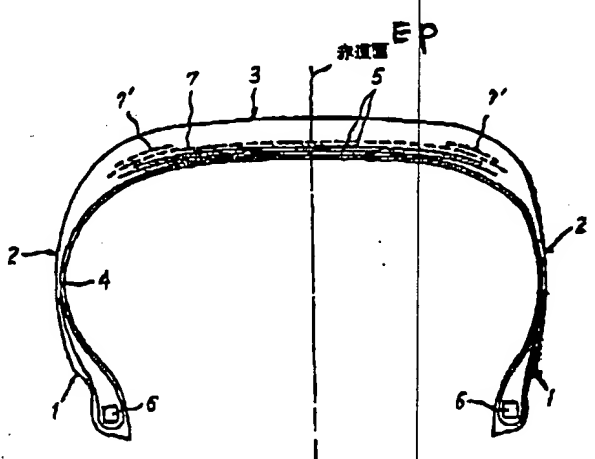
(54) [Title of Invention] Pneumatic radial tire

(57) [Abstract] (Revision has been made)

[Problem] To provide the pneumatic tire for which the vibration riding comfort performance and the operational stability performance are enhanced while the fatigue resistance of the reinforcing layer cord is maintained.



Ep: Equatorial plane

[Means of Solution]

Pneumatic radial tire which is characterized by that,

in the tire which comprises the belt layer, and at least one layer of the belt reinforcing layer at the side of outer periphery of the said belt layer,

the said belt reinforcing layer cord is made of organic fiber ; and

the cord of the shoulder section in the direction of belt width of the said belt reinforcing layer 7' is the double twist yarn obtained by applying the primary twist in such a

way that the specific primary twist number n_1 (S) and the primary twist factor N_1 would be achieved and, after this, a plural number of pieces of the said primary twisted yarn being put together and the final twist being applied in the direction that is reverse to that of the primary twisting such that the specific final twist number n_2 and the primary twist factor N_2 would be achieved; also, in the width direction on tire belt of the said belt reinforcing layer 7, the cord's final twist factor N_2 and the cord's final twist factor N_2 of the center section satisfy certain conditions.

[Claims of the Patent]

[Claim 1] Pneumatic radial tire which is characterized by that,

in the tire which comprises at least one layer of carcass ply layer mounted on a pair of bead cores in a toroidal shape, the belt layer at the outer side in radial direction of tire of the said carcass ply layer, at least one layer of the belt reinforcing layer at the side of outer periphery of the said belt layer and the tread at the side of outer periphery of the said belt reinforcing layer,

the said belt reinforcing layer cord is made of organic fiber ; and

the cord of the shoulder section in the direction of belt width of the said belt reinforcing layer is the double twist yarn obtained by applying the primary twist to the organic fiber yarn in such a way that the primary twist number n_1 (S) and the primary twist factor N_1 (S) would be as defined by the following equations and then applying the final twist , in the opposite direction relative the primary twist, to a plural number of the said primary-twisted yarns together in such a way that the primary twist number n_2 (S) and the primary twist factor N_2 (S) would be as defined by the following equations; and

in the direction of upper width of tire belt in the said belt reinforcing layer, the final twist factor N_2 (S) of the cord of a section of the shoulder and the final twist factor N_2 (S) of the cord of center section satisfy the following equations 1 ~ 3.

[Equation 1] $(D_2/D_1)^{1/2} < N_2\ (S)/N_1\ (S) \leqq 8$
[Equation 2] $0.30 < N_2\ (S) < 0.68$
[Equation 3] $1 < N_2\ (S)/N_2\ (C) < 3$

In Equations 1 ~ 3, if the indicated denier of the primary twisted yarn bundle is denoted by D_1, the total indicated denier by D_2, the primary twist number by n_1 (times/ 10 cm),

the final twist number by n_2 (10 cm), the specific gravity of organic fiber by ρ,

$$N_1 = n_1 \times (0.139 \times D_1/\rho)^{1/2} \times 10^{-3}$$
$$N_2 = n_2 \times (0.139 \times D_2/\rho)^{1/2} \times 10^{-3}$$

[Claim 2] The pneumatic radial tire described in Claim 1 in which the fiber being used in the cord of belt reinforcing layer is polyester fiber, rayon fiber, or polyamide resin fiber.

[Detailed Description of the Invention]

[0001]
[Field of Technology to Which the Invention Belongs] This invention is related to the pneumatic tire in which the double twisted organic fiber is used as the belt reinforcing cord.

[0002]
[Existing Technology] In the past, when the organic resin fiber like polyamide was used in the tire belt reinforcing layer cord, usually, only the so called balanced twist cord in which the primary twist number n_1 and the final twist number n_2 are equal or the so called single twist cord with the primary twist number n_1 = 0 was used regardless of the position in the width direction in the belt. Also, as the recent trend, in order to the suppress the distortion at the belt end section, use of high modulus cord by lower twist number has become frequent. In the case of such cord, however, it is difficult to improve both of high tensile rigidity for suppressing the diameter growth at the high speed rotation of tire and the high elongation for absorbing the tensile input to the cord by the diameter growth without breaking the cord.

[0003] Thereupon, the present inventors found out (Kokai JP No. 237406 - 1995) that the above said problem can be solved by making the ratio of the primary twist factor N_1 and the final twist factor N_2, i.e. N_2/N_1, to be greater than $(D_2/D_1)^{1/2}$ and below 8 and also making the final twist factor to be less than 0.68.

[0004] In such method, however, regardless of the position in the width direction in the belt, one type of cord is used over the whole width and, consequently, as the suppression of the belt end distortion was the main objective, the circumferential direction rigidity of the shoulder section was relatively higher than that of the center section in the tire width direction and so the shoulder - ground contact length was shorter than the center - ground contact length, thus lowering the operational stability performance. Also, over the whole width of tire, absolute value of the circum-

ferential direction rigidity was too high and so the possibility of occurrence of the problem related to the drop in the vibration riding comfort performance was found to exist.

[0005] In view of the above described facts, the present inventors conducted the studies of the relationship between the final twist number and primary twist number of the double twist yarn which is used in the belt reinforcing layer cord of pneumatic tires and of the influence of the tire construction and found out that the above described problem can be solved by changing the final twist factor and the ratio of the primary twist number and final twist number and the final twist factor in the width direction of belt. Thus, this invention was arrived at.

[0006]
[The Problem Which the Invention Intends to Solve] Objective of this invention is to provide the pneumatic tire with enhanced vibration riding comfort and operational stability of tire while maintaining the fatigue resistance of the belt reinforcing layer cord without lowering the tire durability performance.

[0007]
[The Means for Solving the Problem] Thus, this invention is

the pneumatic radial tire which is characterized by that,

in the tire which comprises at least one layer of carcass ply layer mounted on a pair of bead cores in a toroidal shape, the belt layer at the outer side in radial direction of tire of the said carcass ply layer, at least one layer of the belt reinforcing layer at the side of outer periphery of the said belt layer and the tread at the side of outer periphery of the said belt reinforcing layer,

the said belt reinforcing layer cord is made of organic fiber ; and

the cord of the shoulder section in the direction of belt width of the said belt reinforcing layer is the double twist yarn obtained by applying the primary twist to the organic fiber yarn in such a way that the primary twist number n_1 (S) and the primary twist factor N_1 (S) would be as defined by the following equations and then applying the final twist , in the opposite direction relative the primary twist, to a plural number of the said primary-twisted yarns together in such a way that the primary twist number n_2 (S) and the primary twist factor N_2 (S) would be as defined by the following equations; and

in the direction of upper width of tire belt in the said belt reinforcing layer, the final twist factor N_2 (S) of the cord of a section of the shoulder and the final twist factor N_2 (S) of the cord of center section satisfy the following equations 1 ~ 3.

[Equation 1] $(D_2/D_1)^{1/2} < N_2(S)/N_1(S) \leq 8$
[Equation 2] $0.30 < N_2(S) < 0.68$
[Equation 3] $1 < N_2(S)/N_2(C) < 3$

In Equations 1 ~ 3, if the indicated denier of the primary twisted yarn bundle is denoted by D_1, the total indicated denier by D_2, the primary twist number by n_1 (times/ 10 cm), the final twist number by n_2 (10 cm), the specific gravity of organic fiber by ρ,

$$N_1 = n_1 \times (0.139 \times D_1/\rho)^{1/2} \times 10^{-3}$$
$$N_2 = n_2 \times (0.139 \times D_2/\rho)^{1/2} \times 10^{-3}$$

[0008] Also, in this invention, it is desirable that the fiber being used in the cord of belt reinforcing layer is polyester fiber, rayon fiber, or polyamide resin fiber.

[0009]
[Mode of Application of the Invention] For the organic fiber which is used in this invention, the ratio of the primary twist factor N_1 (S) and the final twist factor N_2 (S), i.e. N_2 (S)/ N_1 (S), has to be greater than $(D_2/D_1)^{1/2}$ and less than 8 and also N_2 (S) has to be greater than 0.30 and less than 0.68. If N_2 (S)/ N_1 (S) is less than $(D_2/D_1)^{1/2}$ or greater than 8 and also N_2 (S) is greater than 0.68, the cord's initial tensile rigidity value is low and so the belt end distortion can not be suppressed adequately and this lowers the high speed durability of tire. Also, when N_2 (S) is less than 0.30, breaking elongation of the cord is low and this again reduces the high speed durability. Preferably, $2 \leq N_2(S) / N_1(S) \leq 4$, $0.4 \leq N2(S) \leq 0.6$.

[0010] Also, the final twist factor of the organic fiber cord which is used in the belt reinforcing layer must satisfy

$1 < N_2(S) / N_2(C) < 3$

If this ratio of the final twist numbers of the side section and center section satisfies the above described equation, the heat shrinkage of the cord of shoulder section is large and so, during the vulcanization, cord shrinks and does the tightening to a proper level in the direction of suppressing the belt end distortion during the running and thus secure the high speed durability; also, the initial tensile rigidity of the cord of shoulder section is low and so the circumferential direction rigidity is lower and so the ground-

contacting shape is optimized and so the actual vehicle operability improves. Further, as the final twist factor of the shoulder section is made higher, the total circumferential direction rigidity is suppressed to low and so the vibration at riding over a protrusion does not transmit easily and the vibration riding comfort is improved. Here, if the ratio of the final twist factors of the shoulder section and center section is over 3, the circumferential direction rigidity of the tire center section is relatively too high relative to the circumferential direction rigidity of the tire shoulder section and the center - ground contact length is too short relative to the shoulder - ground contact length; also, if the ratio of the final twist factors of the shoulder section and center section is below 1, the circumferential direction rigidity of the tire shoulder section is relatively too high relative to the circumferential direction rigidity of the tire center section and so the shoulder - ground contact length is too short relative to the center - ground length; thus, in each of these cases, the ground - contact shape is unstable and the operational stability drops. So, it is preferable that $1.5 < N_2 (S) / N_2 (C) < 2.5$. Further, in this invention, for the organic fiber cord which is used at the center section of the belt reinforcing layer, also, one can use one for which the final twist factor and primary twist factor are different. In this case, it is preferred that $(D_2/D_1)^{1/2} < N_2 (C) / N_1 (C) \le 8$, $0.2 \le N_2 (C) \le 0.3$.

[0011] As to the type of organic fiber which is used in this invention, there is no particular question but the polyester fiber such as poly ethylene terephthalate (hereinafter, this is called PET) and poly ethylene naphthalate, the rayon fiber, or the polyamide resin fiber such as nylon 66, nylon 46 and Kevlar are preferred. Among them, nylon 6,6 is preferried from the view point of the total balance of physical properties of cord.

[0012]
[Examples of Application] In the following, the invention is explained in detail by giving examples of application. But the invention is not limited to these examples of application as long as the main point of the invention is not exceeded. Also, in the examples of application, the 'part' and '%' are on the weight basis unless stated otherwise.

[0013] Fig. 1 shows the cross section by the plane which contains the center of rotating axis of the pneumatic tire for passenger car which is due to this invention. In the figure, 1 is the bead section, 2 is the sidewall section, 3 is the tread section, 4 is the carcass ply, 5 is the belt layer, 6 is the bead core, 7 and 7' are the belt reinforcing layers. The carcass ply 4 reinforces a pair of bead sections 1, a pair of the sidewall sections 2 and the tread section 3

and the belt layer 5 reinforces the tread section 3. The belt 5 consists of a plural number (2 layers in the example of the figure) of steel cord layers which are arranged to intersect with each other with the tire's equatorial plane in between. Also, at the side of outer periphery of the belt layer 5, at least one layer of the belt reinforcing layer 7 is comprised (in the example of the figure, there are 2 layers; among them, one layer 7' is comprised only at the belt end). As to the belt reinforcing layer 7, when there are 2 or more layers, it suffices that one layer among them covers the whole belt in the width direction. The pneumatic tire is a radial tire for passenger car having the size of 185 SR14 and its construction follows Fig. 1 and the carcass ply 4 consists of 1 ply. As for the tires of the examples of application, there are 10 examples. To verify the performance and durability of these, 7 examples of the tires of the comparative examples were prepared for which all was same as the examples of application except for the cord of belt reinforcing layer. Also, for references, 2 examples of the tires of existing examples were prepared.

[0014] The organic fiber having cross section of circular shape which was used in the belt reinforcing layer 6 of each tire was obtained from the organic fiber which was prepared by the normal spinning method by double twisting with the prescribed primary twist number and final twist number into cord and then dipping this in the usual dip solution and conducting the adhesive treatment.

[0015] As for the method of preparing the dip solution, Du-Pont Company's recipe IPD-22 was followed. RFL was prepared to the following composition.

	Wt parts
Soft water	592.61
Resorcin	18.20
Formalin (37 %)	26.90
Sodium hydroxide (10 % water solution)	6.60
Vinyl pyridine latex (Note 1)	175.60
Styrene- butadiene- copolymer latex (Note 2)	180.04
Total	1000.00

(Note 1) Latex of trade name JSR0650 made by Nihon Gosei Gomu (K. K.)
(Note 2) Latex of trade name JSR2108 made by Nihon Gosei Gomu (K. K.)

Next, the organic fiber cord which was given the above described dip treatment was dried by the normal method.

[0016] In placing the cord which was prepared as described above into the rubber-coated fabric, number of cords placed in was 50 ea. / 5 cm.

[0017] Measurements of the various types of tire performance were conducted by the methods described below.

1) High speed durability

From the speed of 120 kg/ hr, speed was increased by an increment of 10 km/ hr and, at each speed, tire was run for 20 minutes. The speed (km/ hr) at the occurrence of a disorder was taken as the high speed durability.

[0018] 2) Operability

Inflation pressure of the test tire was adjusted to 1.70 kg/ cm2 and this tire was installed on the drum of OD 3000 mm. The maximum load which is set by JATMA from the size and inflation pressure of the said tire was loaded. After this, the preliminary run was made for 30 minutes at the speed of 30 kg/ hr. In the state under no load, the inflation pressure was readjusted to 1.70 kg/ cm2 and the load of preliminary run was applied again. At the same speed, on the said drum, the slip angle was applied up to a maximum of 14 degrees, positive and negative, continuously. The cornering force (CF) up to the positive and negative angle was measured and the cornering power (CP value) was determined by the following equation.

$$CP\ (Kg/\ ^\circ) = \{\ CF\ (1^\circ)\ (Kg) + CF\ (2^\circ)\ (Kg)/\ 2^\circ + CF\ (3^\circ)\ (Kg)\ /3^\circ + CF\ (4^\circ)\ /\ 4^\circ\}/\ 4$$

Indexing was done by dividing with the CP value of each test tire and taking the control tire as 100. A larger value of this index means better operability.

[0019] 3) Protrusion ride over test

As shown in Fig. 2, at one site on the drum of OD 2000 mm, the protrusion 8 made of iron (upper bottom 10 mm, lower bottom 38 mm, height 9.5 mm) was fixed. The test tire whose inflation pressure was adjusted to 1.70 kg/ cm2 was loaded with the weight which is set by JATMA from the tire size and inflation pressure. At the speed of 80 km/ hr, preliminary run was made for 20 minutes. After this, under no load, the inflation pressure was readjusted to 1.70 kg/ cm2. Speed was set to 20 km/ hr and the weight was adjusted to the load at the preliminary run. After this, the speed was increased by an increment of 5 km/ hr. At each speed, the average wave form in the load fluctuation at the fixed axis of tire at the time of protrusion ride over and the P-P value was calculated. As is clear from Fig. 2, the P-P value is the amplitude up to the maximum value of the fluctuation amplitude of the load on tire axis at the time of the protrusion ride

over. As to the direction of axis load variation at the time of protrusion ride over at the tire fixed axis, measurements were made in the 2 directions, i.e. the tire running direction (forward and backward axis force) and the tire upward and downward direction (upward and downward axis force). As the representative values, the upward and downward axis force and the forward and backward axis force at 2 levels of the speed of 40 km/ hr and 120 km/ hr were indexed. In the indexing, the control tire was taken as 100 and the index was expressed by the following equation.

Test tire index = 100 + 100 x { [P-P(1)] - [P-P(2)] } / [P-P(1)]

where P - P(1) : P-P value of the control tire
P - P(2) : P-P value of the test tire.

The indexing is done such that the index would be larger when the P-P value of the test tire is smaller and a larger index indicates better vibration riding comfort.

[0020] The tests results (1) and (2) described above and the type of cord and construction are shown in Table 1. Test results are given with the Existing Example 1 used as the control tire.

[0021] [Table 1-1]

	EE1 従来例1	C1 比較例1	C2 比較例2	C3 比較例3	C4 比較例4	C5 比較例5	C6 比較例6	EG2 従来例2	C7 比較例7
1. タイヤサイズ					185 / 65 R14				
2. 繊維種	ナイロン	ナイロン	ナイロン	ナイロン	ナイロン	ナイロン	ナイロン	レーヨン	レーヨン
3. 撚り構造	12600/2 1260 D/2	1260D/2	1260D/2	12600/2	1260D/2	1260D/2	12601/2	16500/2	1650D/2
$(D_2/D_1)^{1/2}$	1.41	1.41	1.41	1.41	1.41	1.41	1.41	1.41	1.41
$n_1(C) \times n_2(C)$	39x39	10x16	10x16	10x16	8x14	12x20	7x10	39x39	12x18
$n_1(S) \times n_2(S)$	39x39	34x32	5x32	20x40	8x15	9x18	16x32	39x39	38x36
$N_1(C)$	0.48	0.12	0.12	0.12	0.10	0.15	0.09	0.48	0.15
$N_2(C)$	0.68	0.28	0.28	0.28	0.25	0.35	0.18	0.68	0.32
$N_2(C)/N_1(C)$	1.41	2.26	2.26	2.28	2.47	2.36	2.02	1.41	2.12
$N_1(S)$	0.48	0.42	0.06	0.25	0.10	0.11	0.20	0.48	0.47
$N_2(S)$	0.68	0.56	0.56	0.70	0.26	0.32	0.56	0.68	0.63
$N_2(S)/N_1(S)$	1.41	1.33	9.05	2.83	2.83	2.65	2.83	1.41	1.34
$N_2(S)/N_2(C)$	1.00	2.00	2.00	2.50	1.07	0.90	3.20	2.00	2.00
4. 高速耐久性(km/h)	220	210	210	200	220	230	220	220	210
5. 操縦性	100	98	95	98	97	97	98	99	98
6. 振動乗り心地性	100	97	96	100	95	97	97	100	100

EE1. Existing Example 1; C1. Comparative Example 1;
1. Tire size; 2. Type of fiber; 3. Twisting structure; 4. High speed durability (km/ hr); 5. Operability; 6. Vibration riding comfort

Row 2. EE2, C7. Rayon; All other cases : nylon

*1	:	Nylon 6,6
n_1 (C)	:	Primary twist number of center section
n_1 (S)	:	Primary twist number of shoulder section
n_2 (C)	:	Final twist number of center section
n_2 (S)	:	Final twist number of shoulder section

D_1	:	Nominal denier
D_2	:	Total nominal denier
N_1 (C)	:	Final twist factor of center section
N_1 (S)	:	Final twist factor of shoulder section
N_2 (C)	:	Final twist factor of center section
N_2 (S)	:	Final twist factor of shoulder section

[Table 1-2)

	E1 実施例1	E2 実施例2	E3 実施例3	E4 実施例4	E5 実施例5	E6 実施例6	E7 実施例7	E8 実施例8	E9 実施例9	E10 実施例10
1. タイヤサイズ	185 / 65 R14									
2. 繊維種	ナイロン	ナイロン	ナイロン	ナイロン	ナイロン	ナイロン	ナイロン	ナイロン	ナイロン	レーヨン
3. 撚り構造	1260D/2	1260D/2	1260D/2	1260D/2	1260D/2	1260D/2	1260D/2	1260D/2	840D/3	1650D/2
$(D_2 / D_1)^{1/2}$	1.41	1.41	1.41	1.41	1.41	1.41	1.41	1.41	1.73	1.41
$n_1(C) \times n_2(C)$	10x16	10x16	10x16	10x16	8x12	10x16	10x16	10x16	10x13	12x18
$n_1(S) \times n_2(S)$	30x32	7x32	12x18	24x36	20x32	22x32	16x32	11x32	10x26	18x36
$N_1(C)$	0.12	0.12	0.12	0.12	0.10	0.12	0.12	0.12	0.10	0.15
$N_2(C)$	0.28	0.28	0.28	0.28	0.21	0.28	0.28	0.28	0.23	0.31
$N_2(C) / N_1(C)$	2.26	2.26	2.26	2.26	2.12	2.28	2.26	2.26	2.25	2.12
$N_1(S)$	0.37	0.09	0.15	0.30	0.25	0.27	0.20	0.14	0.16	0.22
$N_2(S)$	0.56	0.56	0.32	0.63	0.56	0.56	0.56	0.56	0.46	0.63
$N_2(S) / N_1(S)$	1.51	6.46	2.12	2.12	2.26	2.06	2.83	4.11	2.81	2.83
$N_2(S) / N_2(C)$	2.00	2.00	1.13	2.25	2.67	2.00	2.00	2.00	2.00	2.00
4. 高速耐久性 (km/h)	220	220	230	220	220	230	240	220	230	240
5. 操縦性	102	102	103	103	102	106	108	105	105	107
6. 振動乗り心地性	103	103	102	102	102	103	103	103	103	103

E1. Example of Application 1;
1. Tire size; 2. Type of fiber; 3. Twisting structure; 4. High speed durability (km/ hr); 5. Operability; 6. Vibration riding comfort

Row 2. E10. Rayon. All other cases: nylon

[0022] In Table 1, Existing Example 1 and Existing Example 2 are the tires using the nylon 6,6 and rayon, respectively, of the balanced twist construction in the belt reinforcing cord. The operability and vibration riding comfort were expressed by using the tire of this Existing Example 1 as the control.

[0023] In Comparative Examples 1, 2, 3, 4, 5, 6, nylon 6,6 was used in the belt reinforcing layer. These are, respectively, the example in which the ratio of final twist factor and primary twist factor in the shoulder section is smaller than the lower limit, the example in which the ratio of final twist factor and primary twist factor in the shoulder section is greater than the upper limit, the example in which the final twist factor in the shoulder section is greater than the upper limit, the example in which the final twist factor in the shoulder section is smaller than the lower limit, the example in which the ratio of final twist factors of the shoulder section and center section is smaller than the lower limit, and the example in which the ratio of final twist factors of the shoulder section and center section is greater than the upper limit. Also, Comparative Example 7 is the case of using rayon in the belt reinforcing layer where the ratio of final twist factor and primary twist factor in the shoulder section is smaller than the lower limit.

[0024] From Comparative Examples 1, 2 and Examples of Application 1, 2, 6, 7, 8, it is seen that, if the ratio of final twist factor and primary twist factor at the shoulder section is in the claimed range of this invention, both of the operational stability and vibration riding comfort improve. From Comparative Examples 3, 4 and Examples of Application 3, 4, it is seen that, if the final twist factor at the shoulder section goes out of the range of this invention, the operational stability is inferior. From Comparative Examples 5, 6 and Examples of Application 3, 4, 5, 7, it is seen that, if the ratio of the final twist factors of the shoulder section and center section is within the range of this application, both of the operational stability and vibration riding comfort improve considerably.

[0025] From Comparative Example 7 and Example of Application 10, it is seen that, even in the case of using rayon cord in the belt reinforcing layer, similar effect is obtained.

[0026] As to the type of tires in which the organic fiber of this invention is used in the belt reinforcing layer, there is no particular restriction but the effect is particularly large when it is used in the passenger car tires or the small truck tires of sizes smaller than 7.50 R16.

[0027]
[Effectiveness of the Invention] By using the organic fiber cord having specific physical properties at the shoulder section of the tire belt reinforcing layer cord, and by limiting its twist construction, the diameter growth at the high speed running can be suppressed and adequate high speed durability of tire can be maintained.

[0028]
[Brief Description of the Figures]

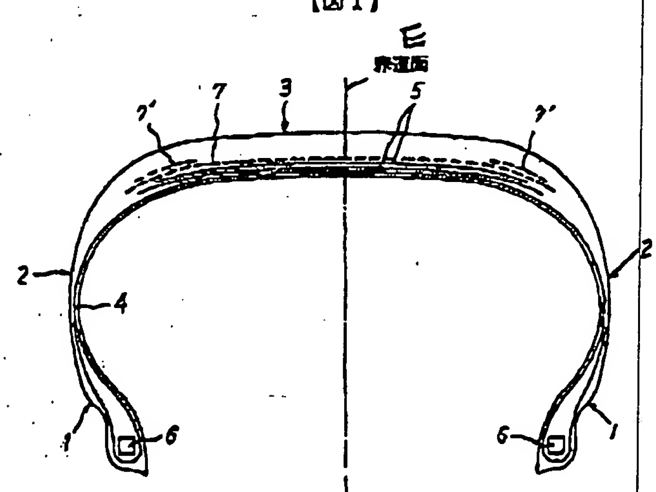
[Fig. 1] shows the cross section by the plane which contains center of the rotating axis of the pneumatic tire for passenger car which is due to this invention.

[Fig. 2] Fig. 2 is the schematic of the protrusion riding-over vibration testing machine.

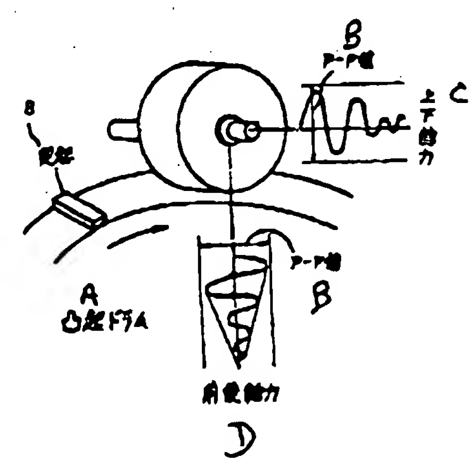
[Explanation of the codes]

1 : Bead section; 2 : Sidewall section ; 3 : Tread section; 4 : Carcass ply; 5 : Belt; 6 : Bead core; 7 : Belt reinforcing layer; 7' : Belt reinforcing layer; 8 : Protrusion made of iron.

【図1】



【図2】



A. Protrusion drum; B. P-P value; C. Upward and downward axis force; D. Forward and back axis force; E. Equatorial plane